



(11) **EP 2 576 488 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:

03.10.2018 Bulletin 2018/40

(21) Application number: **11784310.2**

(22) Date of filing: **20.05.2011**

(51) Int Cl.:

C07C 17/25 (2006.01) **C07C 17/23** (2006.01)
C07C 21/18 (2006.01) **C07C 17/20** (2006.01)
C07C 19/10 (2006.01) **C07C 21/22** (2006.01)
C07C 17/35 (2006.01)

(86) International application number:

PCT/US2011/037310

(87) International publication number:

WO 2011/146820 (24.11.2011 Gazette 2011/47)

(54) **PROCESS FOR CIS-1,1,1,4,4,4,-HEXAFLUORO-2-BUTENE**

VERFAHREN ZUR HERSTELLUNG VON CIS-1,1,1,4,4,4,-HEXAFLUOR-2-BUTEN

PROCÉDÉ DE FABRICATION DU CIS-1,1,1,4,4,4,-HEXAFLUORO-2-BUTÈNE

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(30) Priority: **19.05.2011 US 201113110979**
21.05.2010 US 347134 P

(43) Date of publication of application:
10.04.2013 Bulletin 2013/15

(73) Proprietor: **Honeywell International Inc.**
Morris Plains, NJ 07950 (US)

(72) Inventors:

- **POSS, Andrew Joseph**
Morristown, New Jersey 07962-2245 (US)
- **NALEWAJEK, David**
Morristown, New Jersey 07962-2245 (US)
- **NAIR, Haridasan K.**
Morristown, New Jersey 07962-2245 (US)
- **VAN DER PUY, Michael**
Morristown, New Jersey 07962-2245 (US)

(74) Representative: **Cornish, Kristina Victoria Joy et al**
Kilburn & Strode LLP
Lacon London
84 Theobalds Road
London WC1X 8NL (GB)

(56) References cited:

WO-A1-94/12454 WO-A1-2007/059468
WO-A1-2007/059468 JP-A- 2010 001 244
US-A1- 2008 269 532 US-A1- 2009 156 869
US-B1- 6 399 840

- **HASZELDINE R N: "The addition of free radicals
to unsaturated systems. Part I. The direction of
radical addition to 3 : 3 : 3-trifluoropropene",
JOURNAL OF THE CHEMICAL SOCIETY,
CHEMICAL SOCIETY, LETCHWORTH; GB, 1
January 1952 (1952-01-01), pages 2504-2513,
XP008084552, ISSN: 0368-1769, DOI:
10.1039/JR9520002504**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

CROSS-REFERENCE TO RELATED APPLICATION

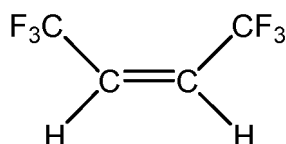
[0001] This application claims domestic priority from commonly owned, copending, U.S. Provisional Patent Application Serial No. 61/347,134, filed 21 May 2010.

BACKGROUND OF THE INVENTION

[0002] Fluorocarbon based fluids have found widespread use in industry in a number of applications, including as refrigerants, aerosol propellants, blowing agents, heat transfer media, and gaseous dielectrics. Because of the suspected environmental problems associated with the use of some of these fluids, including the relatively high global warming potentials (GWP) associated therewith, it is desirable to use fluids having the lowest possible greenhouse warming potential in addition to zero ozone depletion potential (ODP). Thus there is considerable interest in developing environmentally friendlier materials for the applications mentioned above.

[0003] Fluorinated butenes having zero ozone depletion and low global warming potential have been identified as potentially filling this need. However, the toxicity, boiling point, and other physical properties in this class of chemicals vary greatly from isomer to isomer.

[0004] One fluorobutene having valuable properties is cis-1,1,1,4,4,4-hexafluorobutene. Thus, there is a need for new manufacturing processes for the production of hexafluorobutenes and in particular cis-1,1,1,4,4,4-hexafluorobutene:



[0005] There are several methods for producing hexafluoro-2-butene, but such processes may give exclusively the trans-isomer. See, for example, the zinc reduction of 1,1,1,4,4,4-hexafluoro-2-iodobutene; K. Leedham and R. N. Hazeldine, J. Chem. Soc., 1954, 1634.

[0006] Processes that give a mixture of cis- and trans-isomers are likewise undesirable if a substantial proportion of the trans-isomer is formed. One reason is that the difference in boiling points for the two isomers is large (the trans-isomer boiling at about 9°C and the cis-isomer boiling at about 32°C). For applications that depend in large part on the boiling point of the fluorocarbon, the large difference in boiling points may mean that only one isomer is suitable and the other isomer therefore represents a yield loss. Another reason such a mixture is undesirable is that a good means for recycling the undesired trans-isomer is lacking. Ideally, a suitable process will provide the cis:trans isomers in a ratio of 10:1 or better.

[0007] Still other processes for cis-olefins suffer from co-production of the corresponding alkane. In the present case, this means the co-production of 1,1,1,4,4,4-hexafluorobutane. This is likewise undesirable because it does not possess the low GWP that the corresponding butene does. Furthermore, like the trans-isomer, there is no convenient way to recycle this by-product.

[0008] One prior art method for making cis-1,1,1,4,4,4-hexafluorobutene (J. Am. Chem. Soc., 1949, 71, 298) involves reduction of hexafluoro-2-butyne with hydrogen (100 atmospheres) using Raney nickel catalyst at room temperature. Not only does this pressure require specialized equipment, but the conversion was only 82% and the product was a mixture of cis-hexafluoro-2-butene (41 % yield) and hexafluorobutane (25% yield). Ideally the amount of over-reduced material should be less than 10%. Still more preferably, the total amount of trans-isomer and butane are together less than 10%.

[0009] R.N. Hazeldine, J. Chem. Soc., 1952, pp. 2504, also reported the reduction of hexafluorobutyne with Raney nickel at 60°C and 15 atmospheres of hydrogen pressure to give cis-hexafluorobutene. Although some over-reduction to hexafluorobutane was mentioned, the yield of 91 % is substantially better than the yield given in the reference cited above.

[0010] WO 2007/059468 describes the reaction of 3,3,3-trifluoroprop-1-ene with carbon tetrachloride to obtain 2,4,4,4-tetrachloro-1,1,1-trifluorobutane, which is then fluorinated in the presence of C/Cr at 300°C to obtain 1,1,1,4,4,4-hexafluorobut-2-ene.

[0011] A few methods exist for the exclusive preparation of non-fluorinated cis-olefins to the exclusion of the corresponding trans-isomer. The most common of these is the catalytic reduction of alkynes. A number of catalysts may be employed for this transformation but they can, unfortunately, give a wide range of results and undesirable side reactions such as over-reduction to alkanes, formation of trans-olefins, and isomerization of cis to trans olefins. In addition, a wide

range of variables can alter the results, such as temperature, mixing rate, solvent, and added reagents which may intentionally or unintentionally alter the reactivity of the catalyst.

[0012] For a general discussion of this chemistry see, P. N. Rylander, Catalytic Hydrogenation over Platinum Metals, Chapter 4, Academic Press, 1967. For example, depending on the temperature, the reduction of acetylene dicarboxylic acid using Pd on BaSO₄ can give either succinic acid (no double bond) at -18°C or maleic acid (cis double bond) at 100°C, while the ratios of cis to trans products for the reduction of p-methoxy-phenylacetylene carboxylic acid with the same catalyst were similar (20% ± 5% trans isomer) over a wide temperature range. See, S. Takei and M. Ono, Nippon Nogei Kagaku Kaisi 18 (1942b) 119.

[0013] Catalysts that have been used for the selective reduction of non-fluorinated alkynes to alkenes include Pd/C, Pd/BaSO₄, Pd/BaCO₃, and Pd/CaCO₃. In order to achieve high selectivity, however, the use of quinoline as a catalyst modifier has been recommended whether the catalyst is Pd/C, Pd/BaSO₄, or Lindlar catalyst, Pd/CaCO₃/Pb. See, M. Hudlicky, Reductions in Organic Chemistry, 2nd Ed., ACS Monograph 188, 1996, p 8.

[0014] The Lindlar catalyst is probably the most common one used for the reduction of hydrocarbon alkynes to cis-alkenes, modified further by the addition of an aromatic amine such as quinoline or pyridine. The amines, while often useful in improving reaction selectivity, are not desirable from the standpoint of their toxicity. The quality of the quinoline used may also affect the outcome. The Pd/CaCO₃/Pb catalyst, modified with pyridine, was successfully used in the reduction of an alkyne bearing a single fluorine on the carbon adjacent to the triple bond to give the corresponding cis-alkene. See, M. Prakesch, D. Gree, and R. Gree, J. Org. Chem., 66 (2001) 3146. In addition, selective hydrogenation catalyst, such as NanoSelect LF catalyst (obtained from Strem/BASF) may be used to reduce the hexafluorobutene to the desired cis hexafluoro-2-butene.

[0015] As is well known in the art, however, fluorocarbons often behave quite differently compared to non-fluorinated alkanes, and perfluorinated compounds may behave quite differently than even partially fluorinated compounds of similar structure.

SUMMARY OF THE INVENTION

[0016] One embodiment of the present invention is a process for preparing cis-1,1,1,4,4,4-hexafluoropropene comprising the steps as indicated in claim 1.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The first step of the process involves the addition of CCl₄ across the double bond of fluoroolefin of Formula I:



where each X is independently either a halogen or hydrogen, to afford the saturated compound of Formula II:



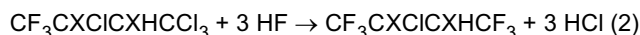
This reaction (Reaction No. 1) is depicted below:



[0018] Typical compounds of Formula I include CF₃CCl=CClH, CF₃CH=CHCl, CF₃CCl=CH₂, CF₃CCl=CFH, CF₃CF=CHCl, CF₃CF=CFH, CF₃CH=CFH, CF₃CF=CH₂, CF₃CH=CFH, CF₃CH=CHBr, CF₃CBr=CH₂, CF₃CBr=CHBr, CF₃CH=CHI, CF₃CI=CHI, CF₃CI=CH₂, and the like.

[0019] Typically the addition of CCl₄ to the olefin of Formula I can be conducted in acetonitrile with CuCl₂ at an elevated temperature of from 100°C to 150°C for a period of about 15 hours as described in J. Fluorine Chem., 1992, 56, 153. After cooling the reactor, the solvent can be evaporated and the residue containing the saturated product of Formula II extracted in a solvent washed with water and dried. Further purification can be accomplished by distillation.

[0020] In the second step the saturated compound is fluorinated with HF as shown below in Reaction No. 2:

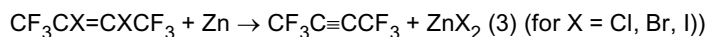
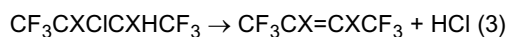


[0021] The fluorination in Reaction No. 2 can be accomplished by procedures in liquid or vapor phase by many reported procedures; see, for example, U.S. Patent Nos. 6,689,924, 6,023,004, or 7,071,368. Although some amounts of over fluorinated compounds such as CF₃CXFCXHCF₃ or CF₃CF₂CXHCF₃ can be formed, reaction conditions are optimized such that the major compound formed on fluorination is as depicted in Reaction No. 2. By-products formation can be

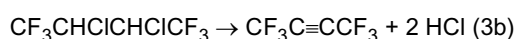
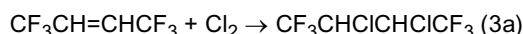
reduced by judicious selection of recants ratio and conditions.

[0022] The continuous vapor phase fluorination of $\text{CF}_3\text{CXClCXHCCl}_3$ with HF and $\text{Cr}_2\text{O}_3/\text{Al}_2\text{O}_3$ catalyst system can also be carried out, for example, as described in WO 9711043 A1.

[0023] The saturated compound thus formed is then subjected to dehydrohalogenation followed by dehalogenation; well known procedures can be found in Chemistry of Organic Fluorine Compounds, 2nd Edition, pages 488- 495, by M. Hudlicky. As shown below for Reaction No. 3, depending on the substituent X, dehydrohalogenation, dehalogenation or both reactions, may be employed.



[0024] In addition, when X = H, an additional steps of adding Cl_2 and subsequent dehalogenations are necessary to afford $\text{CF}_3\text{C}\equiv\text{CCF}_3$ as depicted in Reactions 3a and 3b:



[0025] The liquid phase dehydrohalogenation can be conducted with a base such as aqueous NaOH, KOH and the like, preferably in the presence of a phase transfer catalyst such as tetralkylammonium chloride, crown ethers and the like, as described in U.S. Patent No. 6,548,719.

[0026] Dehalogenation can be conducted by a heating halo compound with Zn metal in a solvent such as acetic anhydride or dioxane at elevated temperature. See, J. Amer. Chem. Soc. 1949, 71, 298; and J. Am. Chem. Soc. 1961, 83, 3424.

[0027] Reduction of $\text{CF}_3\text{C}\equiv\text{CCF}_3$ with hydrogen to cis- $\text{CF}_3\text{CH}=\text{CHCF}_3$ can be done using Lindlar catalyst, and the other catalysts described above.

[0028] The following examples are provided to further illustrate the invention and should not be taken as limitations of the invention.

Example 1

Addition of CCl_4 to $\text{CF}_3\text{CCl}=\text{CHCl}$

[0029] In to a 1 Liter clean, dry stainless steel Parr Reactor was added CCl_4 (154 g, 1.0 mol), followed by CuCl_2 (1.35 g, 0.01 mol) and acetonitrile (50 mL). The reactor was closed, cooled to -20°C and $\text{CF}_3\text{CCl}=\text{CHCl}$ (124 g, 0.75 mol) was introduced as a liquid at about 0°C . The content in the reactor was heated to maintain a temperature of from 130°C to 140°C for 16 hours. After cooling to room temperature (about 20°C), more volatile materials were evaporated and the residue was washed with 1M HCl (50 mL) and water (2 x 100 mL) and dried (MgSO_4). The product was distilled to afford 185 g (77%) $\text{CF}_3\text{CCl}_2\text{CHClCCl}_3$.

[0030] In a similar manner, the reaction was conducted as above except that $\text{CF}_3\text{CCl}=\text{CFH}$ was used as the starting material instead of $\text{CF}_3\text{CCl}=\text{CHCl}$ to afford $\text{CF}_3\text{CCl}_2\text{CFHCCl}_3$ in 80% yield.

Example 2

Fluorination of $\text{CF}_3\text{CCl}_2\text{CHClCCl}_3$

[0031] To a 1 Liter autoclave/Parr reactor was charged SbCl_5 (25 g) and $\text{CF}_3\text{CCl}_2\text{CHClCCl}_3$ (200 g, 0.63 mol) under a nitrogen atmosphere. The reactor was cooled to 0°C and anhydrous HF (120 g) was condensed and added to the reactor. The contents of the autoclave were heated to and maintained at a temperature of from 90°C to 100°C with agitation for 1 hour. As the reaction proceeded an increase in pressure was observed. The reactor was cooled to about 20°C and vented to cold traps. The product in the autoclave was washed with water and caustic solution to afford $\text{CF}_3\text{CCl}_2\text{CHClCF}_3$ (119 g, 70% yield).

[0032] The above reaction was conducted in the same manner except that $\text{CF}_3\text{CCl}_2\text{CFHCCl}_3$ was used instead of $\text{CF}_3\text{CCl}_2\text{CHClCCl}_3$ as the starting material to afford 75% yield of $\text{CF}_3\text{CHClCFHCF}_3$.

[0033] Vapor phase fluorination of $\text{CF}_3\text{CCl}_2\text{CHClCCl}_3$ with $\text{Cr}_2\text{O}_3/\text{Al}_2\text{O}_3$ catalyst was conducted in a similar manner as described in Examples 3-6 of WO 9711043 A1. A 60% to 80% conversion of $\text{CF}_3\text{CCl}_2\text{CHClCCl}_3$ to $\text{CF}_3\text{CCl}_2\text{CHClCF}_3$ was observed.

Example 3

Dehydrohalogenation of $\text{CF}_3\text{CCl}_2\text{CHClCF}_3$

5 **[0034]** To a 500 ml aqueous solution of KOH (20 wt%) containing a phase transfer catalyst (Aliquat 336, 1.5 mmol) at about 0°C in an autoclave was added $\text{CF}_3\text{CCl}_2\text{CHClCF}_3$ (0.2 mol) and stirred for 2 hours. Analysis of the volatile material by gas chromatography indicated the main product as $\text{CF}_3\text{CCl=CClCF}_3$. Further purification was achieved by distillation

10 Example 4

Dehalogenation of $\text{CF}_3\text{CCl=CClCF}_3$

15 **[0035]** Into a 1 Liter flask fitted with a stirrer, a dropping funnel and condenser with an outlet to a cooled trap was charged with Zn dust (40 g, 0.62 mol), acetic anhydride (120 mL) and heated to a temperature range of 130°C to 135°C. To this heated solution was added a solution of $\text{CF}_3\text{CCl=CClCF}_3$ (56 g, 0.24 mol) in 40 mL acetic anhydride over a period of 4 hours. The product $\text{CF}_3\text{C}\equiv\text{CCF}_3$ was removed continuously in a cold trap (-78°C).

Example 5

20

Reduction of $\text{CF}_3\text{C}\equiv\text{CCF}_3$ to cis- $\text{CF}_3\text{CH=CHCF}_3$

25 **[0036]** A 1 L clean, dry autoclave was charged with 3.0 g catalyst (5% Pd on CaCO_3 poisoned with 3.5% lead) and 240 mL ethanol. The content in the autoclave was cooled to -78°C and air inside the reactor was removed by purging with nitrogen after evacuating; this was repeated twice. After this 48 g $\text{CF}_3\text{C}\equiv\text{CCF}_3$ was condensed and the contents were brought to room temperature. Hydrogen was added such a way that the pressure in the reactor was maintained below about 90 psi and stirred for 20 hours at temperature range of 25°C to 30°C. The content in the autoclave was cooled (-78°C), and H_2 gas was vented. The material in the autoclave was distilled to afford cis- $\text{CF}_3\text{CH=CHCF}_3$ (42 g, 86% yield). Further purification can be accomplished via distillation at 30°C to 32°C.

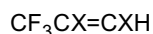
30 **[0037]** In a similar manner, the reaction was carried as above except for the fact that NanoSelect LF 100 or NanoSelect LF 200 (Strem Chemicals, Inc.) catalyst was used instead 5% Pd on CaCO_3 poisoned with 3.5% lead to afford 60% yield of cis- $\text{CF}_3\text{CH=CHCF}_3$.

35 **Claims**

1. A process for preparing cis-1,1,1,4,4,4-hexafluorobut-2-ene comprising steps:

(a) reacting CCl_4 with a compound having the formula:

40



where X = halogen or H independent of each other, to form a compound having the formula:

45



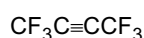
(b) fluorinating the compound formed in step (a) to form a compound having the formula:

50



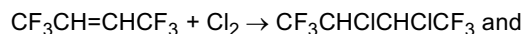
(c) converting the compound formed in step (b) by a reaction selected from the group consisting of dehydrohalogenation, dehalogenation and both reactions, to form a compound having the formula:

55

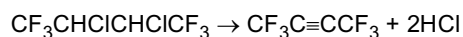


wherein when X=H, step (c) comprises the steps of

1) adding Cl_2 :

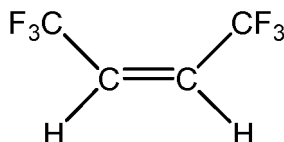


2) a subsequent dehalogenation step:



and

(d) catalytically reducing the compound formed in step (c) with hydrogen to form the compound having the formula:



2. The process of Claim 1, wherein any of the steps can be run in a continuous manner.

3. The process of Claim 1, wherein the compound $\text{CF}_3\text{CX}=\text{CXH}$ is $\text{CF}_3\text{CCl}=\text{CHCl}$.

4. The process of Claim 1, wherein the compound $\text{CF}_3\text{CX}=\text{CXH}$ is $\text{CF}_3\text{CCl}=\text{CFH}$.

5. The process of Claim 1, wherein the compound $\text{CF}_3\text{CXClCXHCCl}_3$ is $\text{CF}_3\text{CCl}_2\text{CHClCCl}_3$.

6. The process of Claim 1, wherein the compound $\text{CF}_3\text{CXClCXHCCl}_3$ is $\text{CF}_3\text{CCl}_2\text{CFHCCl}_3$.

7. The process of Claim 1, wherein the compound $\text{CF}_3\text{CX}=\text{CXH}$ is selected from the group consisting of $\text{CF}_3\text{CCl}=\text{CClH}$, $\text{CF}_3\text{CH}=\text{CHCl}$, $\text{CF}_3\text{CCl}=\text{CH}_2$, $\text{CF}_3\text{CCl}=\text{CFH}$, $\text{CF}_3\text{CF}=\text{CHCl}$, $\text{CF}_3\text{CF}=\text{CFH}$, $\text{CF}_3\text{CH}=\text{CFH}$, $\text{CF}_3\text{CF}=\text{CH}_2$, $\text{CF}_3\text{CH}=\text{CFH}$, $\text{CF}_3\text{CH}=\text{CHBr}$, $\text{CF}_3\text{CBr}=\text{CH}_2$, $\text{CF}_3\text{CBr}=\text{CHBr}$, $\text{CF}_3\text{CH}=\text{CHI}$, $\text{CF}_3\text{Cl}=\text{CHI}$, and $\text{CF}_3\text{Cl}=\text{CH}_2$.

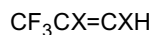
8. The process of Claim 1, wherein the step (c) reaction comprises dehydrohalogenation of $\text{CF}_3\text{CXHCXHCFCF}_3$.

9. The process of Claim 1, wherein the step (c) reaction comprises dehalogenation of $\text{CF}_3\text{CXHCXHCFCF}_3$.

Patentansprüche

1. Verfahren zur Herstellung von cis-1,1,1,4,4,4-Hexa-fluorbut-2-en, das folgende Schritte umfasst:

(a) Umsetzen von CCl_4 mit einer Verbindung der Formel:



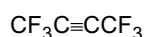
wobei X unabhängig voneinander = Halogen oder H, zur Bildung einer Verbindung der Formel:



(b) Fluorieren der in Schritt (a) gebildeten Verbindung zur Bildung einer Verbindung der Formel:

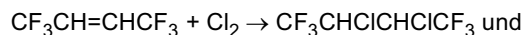


(c) Umwandeln der in Schritt (b) gebildeten Verbindung durch eine Reaktion aus der Gruppe bestehend aus Dehydrohalogenierung, Dehalogenierung und beiden Reaktionen zur Bildung einer Verbindung der Formel:

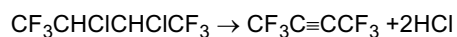


wobei im Fall von X = H Schritt (c) die Schritte

1) Addieren von Cl₂:

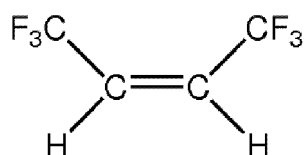


2) einen anschließenden Dehalogenierungsschritt:



umfasst, und

(d) katalytisches Reduzieren der in Schritt (c) gebildeten Verbindung mit Wasserstoff zur Bildung der Verbindung der Formel:

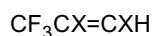


2. Verfahren nach Anspruch 1, bei dem jeder der Schritte kontinuierlich durchgeführt werden kann.
3. Verfahren nach Anspruch 1, bei dem es sich bei der Verbindung CF₃CX=CH um CF₃CCl=CHCl handelt.
4. Verfahren nach Anspruch 1, bei dem es sich bei der Verbindung CF₃CX=CH um CF₃CCl=CFH handelt.
5. Verfahren nach Anspruch 1, bei dem es sich bei der Verbindung CF₃CXCICXHCCl₃ um CF₃CCl₂CHClCCl₃ handelt.
6. Verfahren nach Anspruch 1, bei dem es sich bei der Verbindung CF₃CXCICXHCCl₃ um CF₃CCl₂CFHCCl₃ handelt.
7. Verfahren nach Anspruch 1, bei dem die Verbindung CF₃CX=CH aus der Gruppe bestehend aus CF₃CCl=CClH, CF₃CH=CHCl, CF₃CCl=CH₂, CF₃CCl=CFH, CF₃CF=CHCl, CF₃CF=CFH, CF₃CH=CFH, CF₃CF=CH₂, CF₃CH=CFH, CF₃CH=CHBr, CF₃CBr=CH₂, CF₃CBr=CHBr, CF₃CH=CHI, CF₃Cl=CHI und CF₃Cl=CH₂ ausgewählt wird.
8. Verfahren nach Anspruch 1, bei dem die Reaktion von Schritt (c) die Dehydrohalogenierung von CF₃CXHCXHCFC₃ umfasst.
9. Verfahren nach Anspruch 1, bei dem die Reaktion von Schritt (c) die Dehalogenierung von CF₃CXHCXHCFC₃ umfasst.

Revendications

1. Procédé pour la préparation de cis-1,1,1,4,4,4-hexafluorobut-2-ène comprenant les étapes :

(a) réaction de CCl₄ avec un composé répondant à la formule :



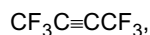
où chaque X indépendamment de l'autre = un halogène ou H, pour former un composé répondant à la formule :



(b) fluoration du composé formé dans l'étape (a) pour former un composé répondant à la formule :

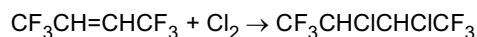


(c) conversion du composé formé dans l'étape (b) par une réaction choisie dans le groupe constitué par une déshydrohalogénéation, une déshalogénéation ou les deux réactions, pour former un composé répondant à la formule :



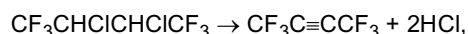
lorsque X = H, l'étape (c) comprenant les étapes de

1) ajout de Cl_2 :



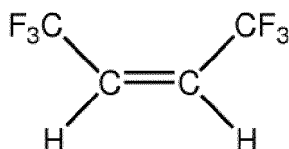
et

2) une étape de déshalogénéation subséquente :



et

(d) réduction catalytique du composé formé dans l'étape (c) avec de l'hydrogène pour former le composé répondant à la formule :



2. Procédé selon la revendication 1, dans lequel l'une quelconque des étapes peut être mise en oeuvre d'une manière continue.
3. Procédé selon la revendication 1, dans lequel le composé $\text{CF}_3\text{CX}=\text{CXH}$ est $\text{CF}_3\text{CCl}=\text{CHCl}$.
4. Procédé selon la revendication 1, dans lequel le composé $\text{CF}_3\text{CX}=\text{CXH}$ est $\text{CF}_3\text{CCl}=\text{CFH}$.
5. Procédé selon la revendication 1, dans lequel le composé $\text{CF}_3\text{CXCICXHCCl}_3$ est $\text{CF}_3\text{CCl}_2\text{CHClCCl}_3$.
6. Procédé selon la revendication 1, dans lequel le composé $\text{CF}_3\text{CXCICXHCCl}_3$ est $\text{CF}_3\text{CCl}_2\text{CFHCCl}_3$.
7. Procédé selon la revendication 1, dans lequel le composé $\text{CF}_3\text{CX}=\text{CXH}$ est choisi dans le groupe constitué par $\text{CF}_3\text{CCl}=\text{CClH}$, $\text{CF}_3\text{CH}=\text{CHCl}$, $\text{CF}_3\text{CCl}=\text{CH}_2$, $\text{CF}_3\text{CCl}=\text{CFH}$, $\text{CF}_3\text{CF}=\text{CHCl}$, $\text{CF}_3\text{CF}=\text{CFH}$, $\text{CF}_3\text{CH}=\text{CFH}$, $\text{CF}_3\text{CF}=\text{CH}_2$, $\text{CF}_3\text{CH}=\text{CFH}$, $\text{CF}_3\text{CH}=\text{CHBr}$, $\text{CF}_3\text{CBr}=\text{CH}_2$, $\text{CF}_3\text{CBr}=\text{CHBr}$, $\text{CF}_3\text{CH}=\text{CHI}$, $\text{CF}_3\text{Cl}=\text{CHI}$ et $\text{CF}_3\text{Cl}=\text{CH}_2$.
8. Procédé selon la revendication 1, dans lequel la réaction de l'étape (c) comprend la déshydrohalogénéation de $\text{CF}_3\text{CXHCXHCFCF}_3$.
9. Procédé selon la revendication 1, dans lequel la réaction de l'étape (c) comprend la déshalogénéation de $\text{CF}_3\text{CXHCXHCFCF}_3$.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 61347134 A [0001]
- WO 2007059468 A [0010]
- US 6689924 B [0021]
- US 6023004 A [0021]
- US 7071368 B [0021]
- WO 9711043 A1 [0022] [0033]
- US 6548719 B [0025]

Non-patent literature cited in the description

- **K. LEEDHAM ; R. N. HAZELDINE.** *J. Chem. Soc.*, 1954, 1634 [0005]
- *J. Am. Chem. Soc.*, 1949, vol. 71, 298 [0008]
- **R.N. HAZELDINE.** *J. Chem. Soc.*, 1952, 2504 [0009]
- **P. N. RYLANDER.** Catalytic Hydrogenation over Platinum Metals. Academic Press, 1967 [0012]
- **S. TAKEI ; M. ONO.** *Nippon Nogei Kagaku Kaisi*, 1942, vol. 18, 119 [0012]
- Reductions in Organic Chemistry. **M. HUDLICKY.** ACS Monograph. 1996, vol. 188, 8 [0013]
- **M. PRAKESCH ; D. GREE ; R. GREE.** *J. Org. Chem.*, 2001, vol. 66, 3146 [0014]
- *J. Fluorine Chem.*, 1992, vol. 56, 153 [0019]
- **M. HUDLICKY.** Chemistry of Organic Fluorine Compounds. 488-495 [0023]
- *J. Amer. Chem. Soc.*, 1949, vol. 71, 298 [0026]
- *J. Am. Chem. Soc.*, 1961, vol. 83, 3424 [0026]